



Technical Data Sheet

GENERAL

ATI Ti-15Mo Titanium Alloys (UNS R58150) are formulated from two metals with greatly different elemental densities. To ensure complete melting and to minimize molybdenum segregation, these alloys are melted in a plasma arc furnace and remelted in a VAR furnace. Several molybdenum containing titanium alloys are commonly used in the aerospace industry, including: ATI Ti-8Al-1Mo-1V, ATI Ti-6Al-2Sn-4Zr-2Mo, and ATI Ti-3Al-8V-6Cr-4Mo-4Zr. ATI Ti-15Mo alloy was “rediscovered” by the medical industry because of its unique combination of properties; exceptional corrosion resistance, attractive mechanical properties, and well-documented biocompatibility¹. ATI Ti-15Mo alloys are manufactured as bar, rod, sheet, and wire product forms for orthopaedic, trauma, spinal, dental, orthodontic, and cardiovascular applications.

STRUCTURES

ATI Ti-15Mo alloy with oxygen content up to a maximum of 0.20% can be supplied to ASTM F 2066 as a metastable beta titanium alloy, with a fully recrystallized beta phase (bcc) structure. In the solution annealed condition, the alloy has a modulus of elasticity that is about two-thirds the modulus of ATI Ti-6Al-4V alloy, along with considerably improved ductility and corrosion fatigue properties^{2,3}.

Alternatively, the two-phase alpha (hcp) plus beta (bcc) structure enables optimum control of the microstructure during subsequent transformations, when the alloys are aged after cooling from a forging or solution heat-treatment temperature⁴. Alpha-beta ATI Ti-15Mo alloys can provide an optimum combination of strength and ductility, whereas beta ATI Ti-15Mo alloy provides better ductility and formability.

Finally, a micro-grained alpha-plus-beta phase ATI Ti-15Mo alloy exhibiting very high notched corrosion fatigue strength but with remarkable ductility has been invented⁵. For applications that anticipate heavy loading along with high cycle fatigue conditions, this alloy is a superior choice over ATI Ti-6Al-4V or ATI Ti-6Al-4V ELI alloys.

SPECIFICATIONS

- ASTM F 2066 - Bar, Rod, Sheet, and Wire
 - Beta Annealed Condition
 - Alpha-plus-Beta Annealed Condition

PHYSICAL PROPERTIES

Melting Range: 3,100-3,200° F (1,704-1,760° C)

Density: 0.179 lbs/cu. in.; 4.95 gm/cc

Beta Transus Temperature: 1,425° F (± 25 F°); 774° C (± 14 C°)

Elastic Modulus: 78 GPa in the solution annealed (beta annealed) condition according to F 2066

HEAT TREATMENT

ATI Ti-15Mo alloy that is supplied in the solution annealed and quenched condition has a fully recrystallized beta phase structure.

1. Anneal: 1,450 - 1,800° F (788 - 982° C), 1 hour, rapid quench to below 1,025° F (552° C).
2. Stress Relief: 1,500° F (816° C), 10 minutes, rapid quench to below 1,025° F (552° C).

ATI Ti-15Mo alloy that is processed above the beta transus and is slow cooled will have an alpha plus beta phase structure.

1. Anneal: 1,450 - 1,800° F (788 - 982° C), 1 hour, slow cool to below 1,025° F (552° C).
2. Stress Relief: 1,500° F (816° C), 10 minutes, slow cool to below 1,025° F (552° C).

HARDNESS

In the annealed and quenched condition, with a fully recrystallized beta phase microstructure, the strength values of ATI Ti-15Mo alloy are moderate and the ductility values are relatively high. Hardness is in the HRc 22-26 range.

FORGEABILITY/ FORMABILITY

Hot and cold workability characteristics of ATI Ti-15Mo alloy are very good, which is typical for beta titanium alloys^{6,7}. The low elastic modulus and exceptional ductility of this alloy are properties that contribute to an unusual springiness or “spring back” in forming and in machining. ATI Ti-15Mo alloy can be finish forged above the beta transus from 1,500° F (816° C) with a finishing temperature in the alpha plus beta region or about 1,200° F (649° C). An immediate water quench minimizes the formation of omega phase in thin sections of this alloy, depending upon the microstructural properties desired.

ATI Ti-15Mo Beta Titanium Alloy

ATI Ti-15Mo $\alpha + \beta$ Titanium Alloys



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MACHINABILITY

ATI Ti-15Mo alloys can be machined with new and sharp tools using higher feed rates and reduced machining speeds. It is important to irrigate the tooling and workpiece well with large amounts of non-chlorinated cutting fluid. Alternative metal removal methods such as water jet cutting, wire EDM, and plasma cutting have been used successfully for ATI Ti-15Mo alloy components. Take special care to avoid hydrogen, oxygen, and nitrogen pick-up at exposed surfaces when performing machining, cutting, or grinding operations.

SPECIAL PRECAUTIONS

ATI Ti-15Mo alloys can be subject to hydrogen contamination during improper pickling and to oxygen, nitrogen, and carbon pickup during forging, heat treating, grinding, etc. This contamination may cause a reduction in ductility which could adversely affect notch sensitivity and forming characteristics.

Chemical Composition							
	N	C	H	Fe	O	Mo	Ti
% w/w, min.	-	-	-	-	-	14.00	Bal
% w/w, max.	0.05	0.10	0.015	0.10	0.20	16.00	Bal

Mechanical Properties: ATI Beta Ti-15Mo Alloy, and ATI Alpha plus Beta T-15Mo Alloys						
	Product Form and Condition	Thickness, inches	UTS, min. ksi (MPa)	YS 0.2%, min. ksi, (MPa)	%EL, min.	%RA, min.
ASTM F 2066	Bar, Rod, and Wire; Hot or Cold Rolled, Beta Annealed, Cold Finished	Up to 3.625 in., diameter or thickness	100 (690)	70 (483)	20	40
ASTM F 2066	Bar, Rod, and Wire Hot or Cold Rolled, Beta Annealed, Cold Finished	Up to 3.625 in., diameter or thickness	130.5 (900)	116 (800)	10	25
ASTM F 2066	Sheet, Strip, and Plate; Hot or Cold Rolled, Beta Annealed, Cold Finished	Special Requirements by Agreement	105 (724)	80 (552)	12	Bend Test

Specification minimum values. Mechanical properties as a function of oxygen content have been studied ⁹.

CORROSION RESISTANCE AND BIOCOMPATIBILITY

The passive oxide film on the surface of titanium and titanium alloys is resistant to tarnish and corrosion, and also contributes to biocompatibility and osseointegratability. A tenacious mixture of metal oxides forms rapidly on the surface of any CP grade or alloy of titanium. The chemical make-up of this adherent oxide layer is a function of the chemical composition of the titanium base metal. Titanium base metal composition and the surface oxide film are important determinants of corrosion resistance, biocompatibility, and osseointegratability. ATI Ti-15Mo alloys and ATI CP titanium exhibit better corrosion resistance in phosphate buffered saline solutions than ATI Ti-6Al-4V ELI and ATI Ti-6Al-7Nb. Anodic polarization measurements show that ATI Ti-15Mo alloys performs better in a test corrosive environment than ATI Ti CP-4, ATI Ti-6Al-4V ELI, and ATI Ti-6Al-7Nb alloys ⁹.

NOTCH SENSITIVITY

Test methods ASTM E 8 are used for tensile testing of smooth tensile specimens, and method ASTM E 602 is employed for sharp-notch tensile specimens. ATI Ti-15Mo alloys, in the beta and the alpha plus beta conditions, have superior notch sensitivity resistance when compared with conventional $\alpha + \beta$ titanium alloys, ATI Ti-6Al-4V ELI and ATI Ti-6Al-7Nb ¹⁰. This is an important materials property to be considered for devices subject to scratching and for components with holes, threads, sharp edges, and in contact with other components in an implant construct.

STRESS CORROSION CRACKING (SCC) RESISTANCE

The stress corrosion cracking properties of four implantable titanium grades was investigated at the University of Mississippi Medical Center ^{11,12,16}. Comparable test data were generated for ATI Ti CP-4 (ASTM F 67, α microstructure), ATI Ti-6Al-4V ELI (ASTM F 136, α/β microstructure), ATI Ti-6Al-7Nb (ASTM F 1295, α/β microstructure), and ATI Ti-15Mo (ASTM F 2066, β and α/β microstructures). ATI Ti-15Mo alloys are not susceptible to SCC under the conditions tested at UMMC, nor are any of the other three titanium grades tested.

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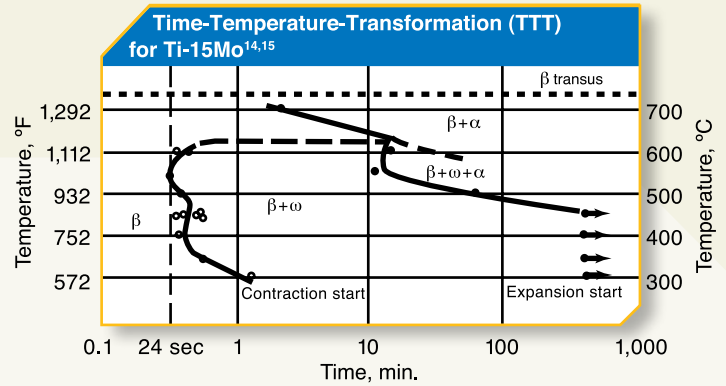
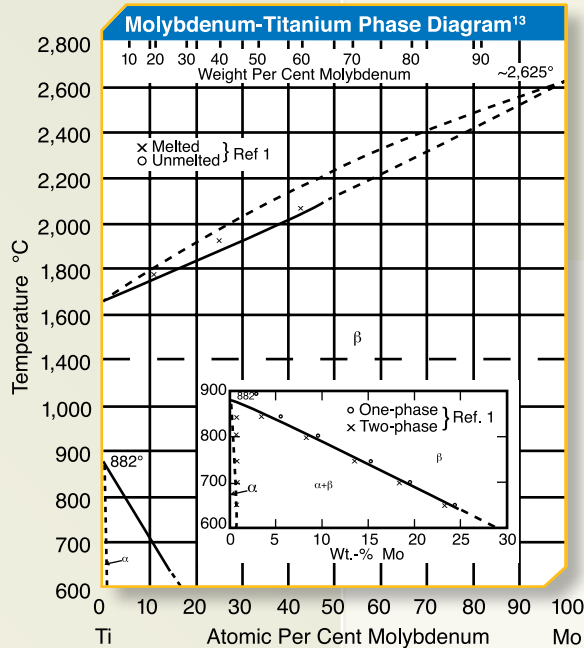
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ATI Ti-15Mo Beta Titanium Alloy

ATI Ti-15Mo $\alpha + \beta$ Titanium Alloys



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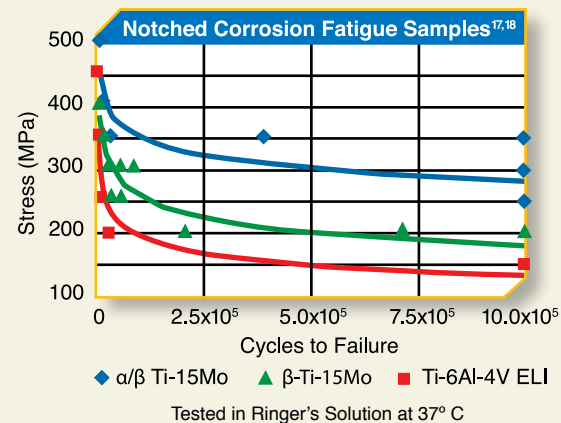
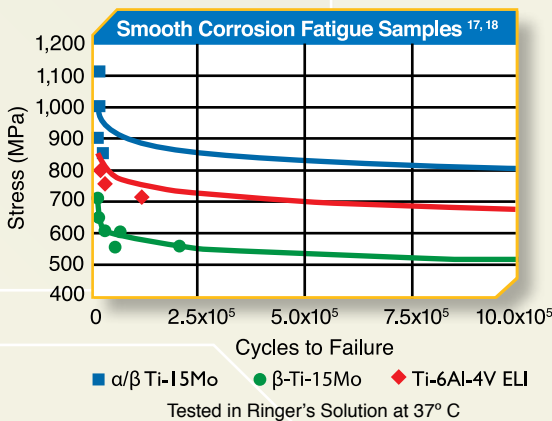


ATI Ti-15Mo $\alpha + \beta$ TITANIUM ALLOY, WITH MICRO-GRAINED STRUCTURE

Stress Corrosion Cracking; Smooth and Notched Corrosion Fatigue Strengths^{5,15}

Zardiackas et. al. studied ATI Ti-15Mo alloys that meet ASTM F 2066 chemistry in the alpha plus beta condition, with special processing to achieve a uniform, micro-grained structure. Comparisons were made with wrought ATI Ti-6Al-4V ELI (ASTM F 136, α/β) and ATI Ti-15Mo (ASTM F 2066, β) alloys. Corrosion fatigue testing was performed in tension-tension on smooth and notched samples in both aerated distilled/de-ionized water and aerated Ringer's solution at 37°C. Fatigue testing followed the guidelines of ASTM F1801 using the given R ($\sigma_{min}/\sigma_{max}$) value of 0.053.

Fatigue curves for the smooth samples show higher fatigue strength for ATI Ti-15Mo α/β alloy regardless of stress level when compared with the other titanium alloys. In the smooth condition, tested in Ringer's solution, the ATI Ti-15Mo α/β alloy had a fatigue runout limit of 800 MPa as compared to 700 MPa for ATI Ti-6Al-4V ELI alloy, and 500 MPa for ATI Ti-15Mo β alloy¹⁷. Fatigue curves for the notched samples tested in Ringer's solution show the ATI Ti-15Mo α/β notched samples have a fatigue run-out limit of between 250 MPa and 300 MPa in Ringer's solution, compared with 150 MPa for ATI Ti-6Al-4V ELI, and 200 MPa for ATI Ti-15Mo β samples.



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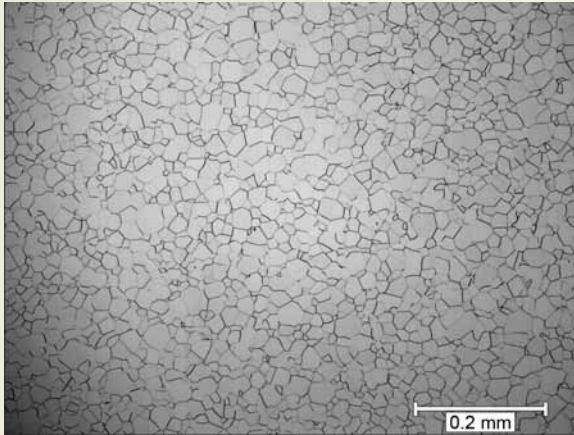
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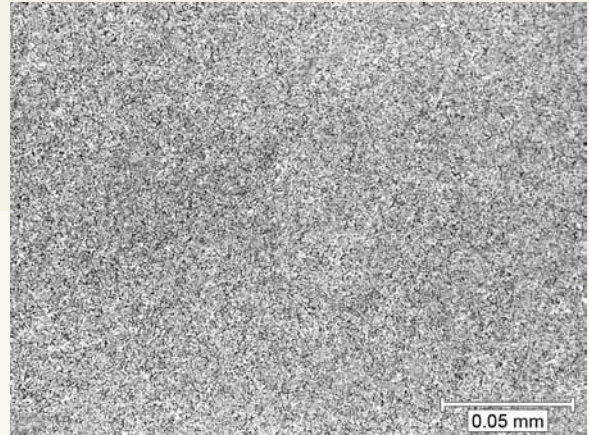


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METALLOGRAPHY



ATI Ti-15Mo Beta Titanium Alloy, 100 X



ATI Ti-15Mo Alpha + Beta Titanium Alloy, 500X
(with micro-grained structure)

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